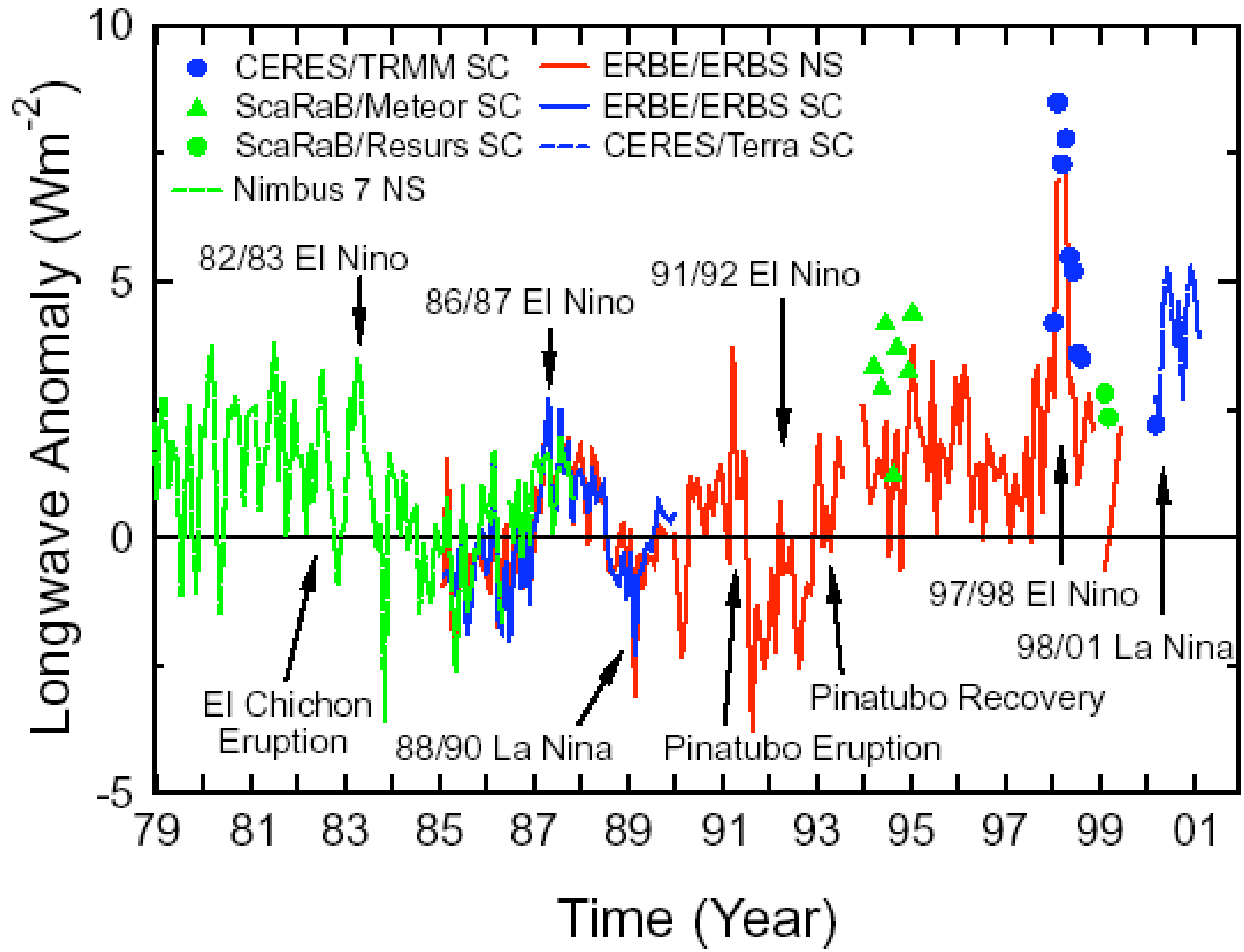
How do CERES interannual variations fit with Earthshine, Deep Ocean, etc?

Bruce A. Wielicki

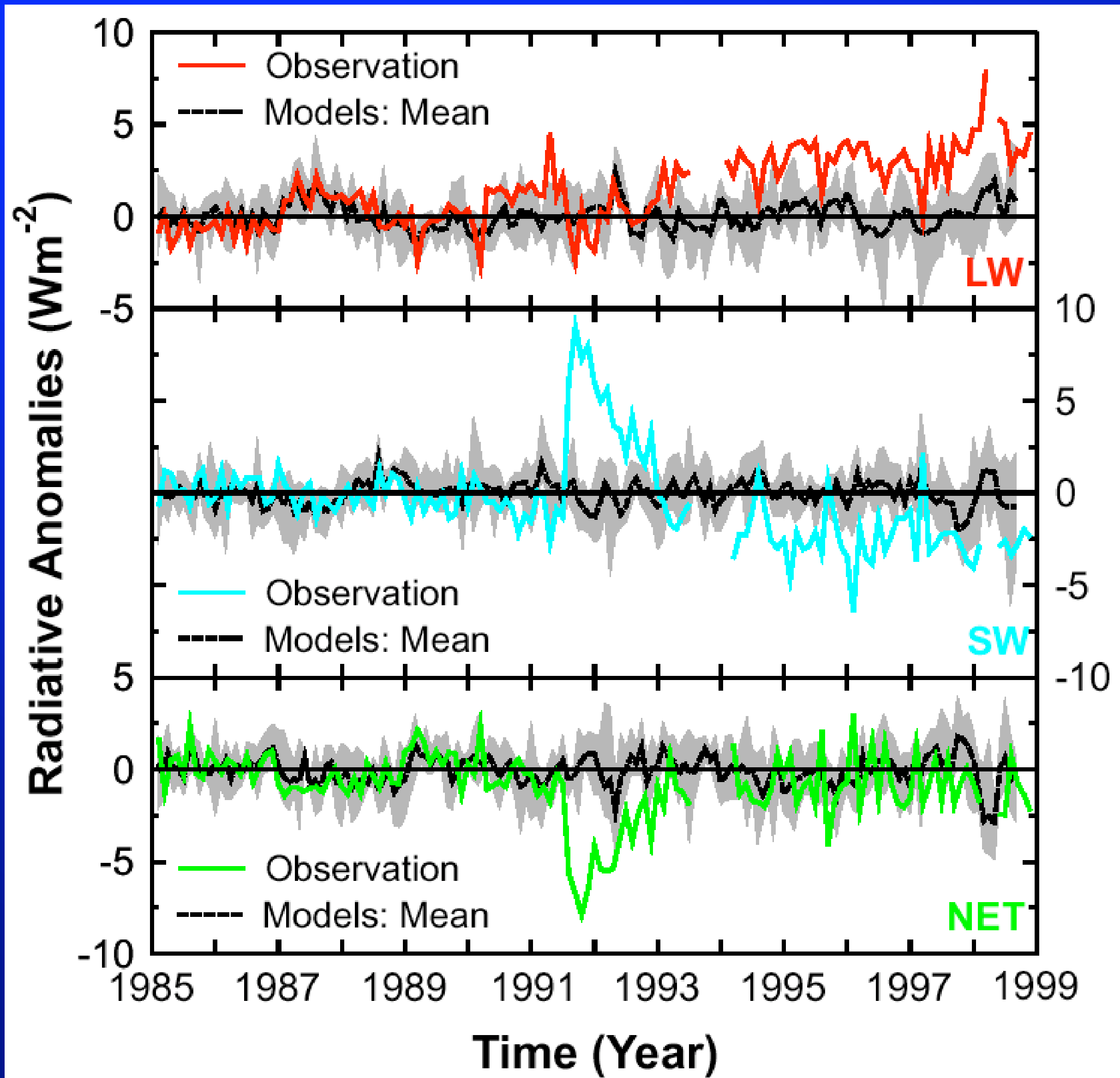
2nd CERES-II Science Team Meeting
Williamsburg, VA
Nov 2-4, 2004

Recall the Science 2002 Results on Tropical LW fluxes....



Wielicki et al. Science 2002 Modified to include ERBS Altitude Correction

Comparison of Observed Decadal Tropical Radiation Variation with Current Climate Models



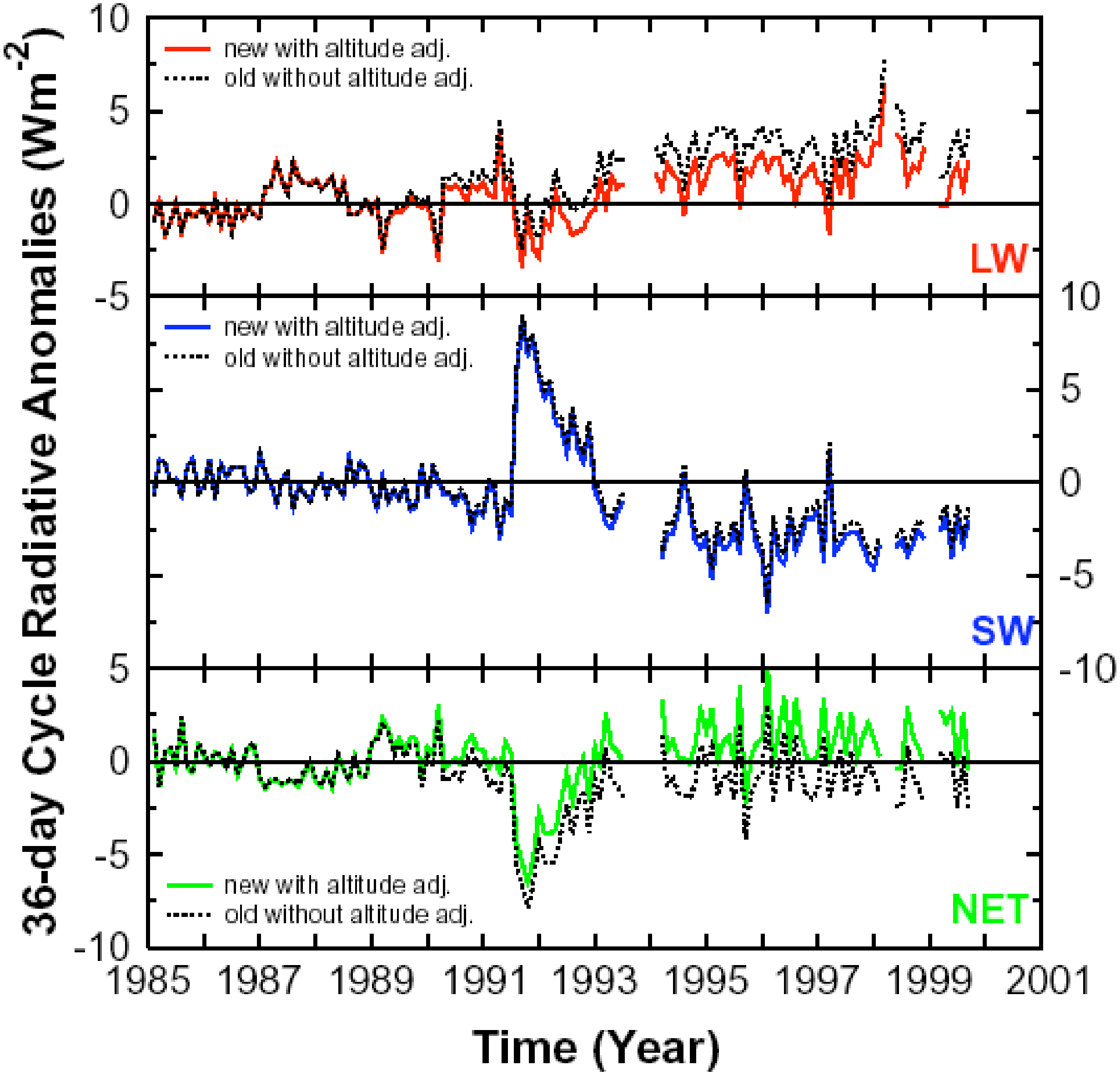
LW:
Emitted Thermal Fluxes

SW:
Reflected Solar Fluxes

Net:
Net Radiative Fluxes

Models less variable than the observations:
- missing feedbacks?
- missing forcings?
- clouds physics?

ERBS Altitude Adjusted TOA Flux Anomalies vs Science 2002



ERBS Altitude Adjustment (600km to 580km)

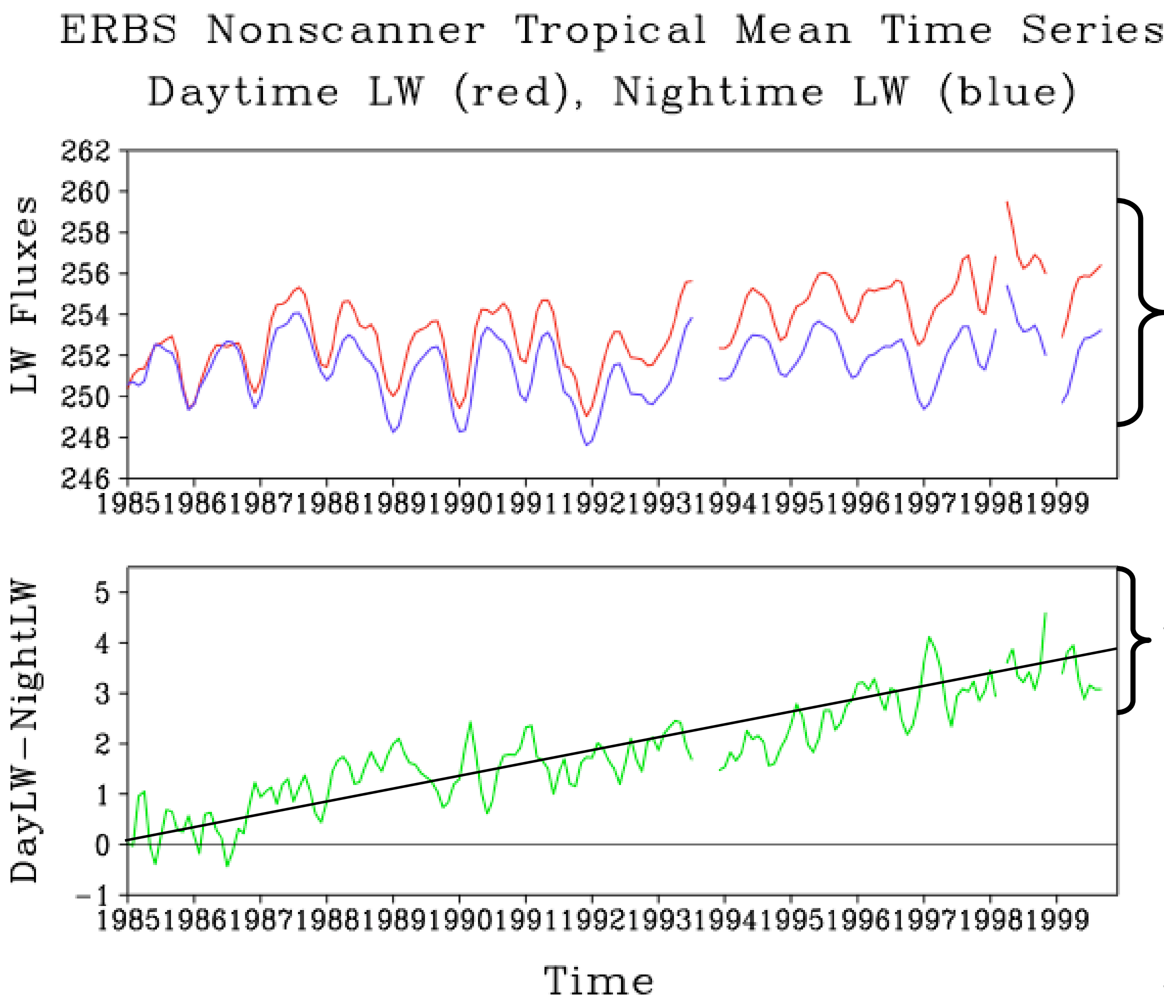
Science, 2002
94-97 minus 85-89
SW anomaly: - 2.5
LW anomaly: + 3.1
Net anomaly: - 0.6
(net cooling)

Altitude Corrected Values:
SW anomaly: - 3.1
LW anomaly: + 1.6
Net anomaly: - 1.5
(net heating)

ERBS data being reprocessed this summer (Edition 3) & released this fall.

ERBS Day LW vs Night LW check: Edition 3

(Ocean heat storage only constrains ERBS Total Channel)



If LW trends are the same day and night, then different day/night LW trends imply changes in ERBS SW channel

3.7 Wm^{-2} in 15 years
1.8% in 15 years of daytime SW flux

(97-94 avg) - (89-85 avg) = 8.5 yrs
1.8% (8.5/15) = 1% = 1 Wm^{-2} SW flux
If make these changes to ERBS trends
Net flux trend: no effect: + 1.5 Wm^{-2}
SW flux trend: -3.1 to -2.1 Wm^{-2}
LW flux trend: +1.6 to +0.6 Wm^{-2}

Potential source of SW trend? SW dome loss of 8% is underestimated by 1% due to nonuniform solar exposure over dome (edges more highly exposed): Smith estimate < 0.5%

What is consistency of resulting ERBS trends with other data sets?

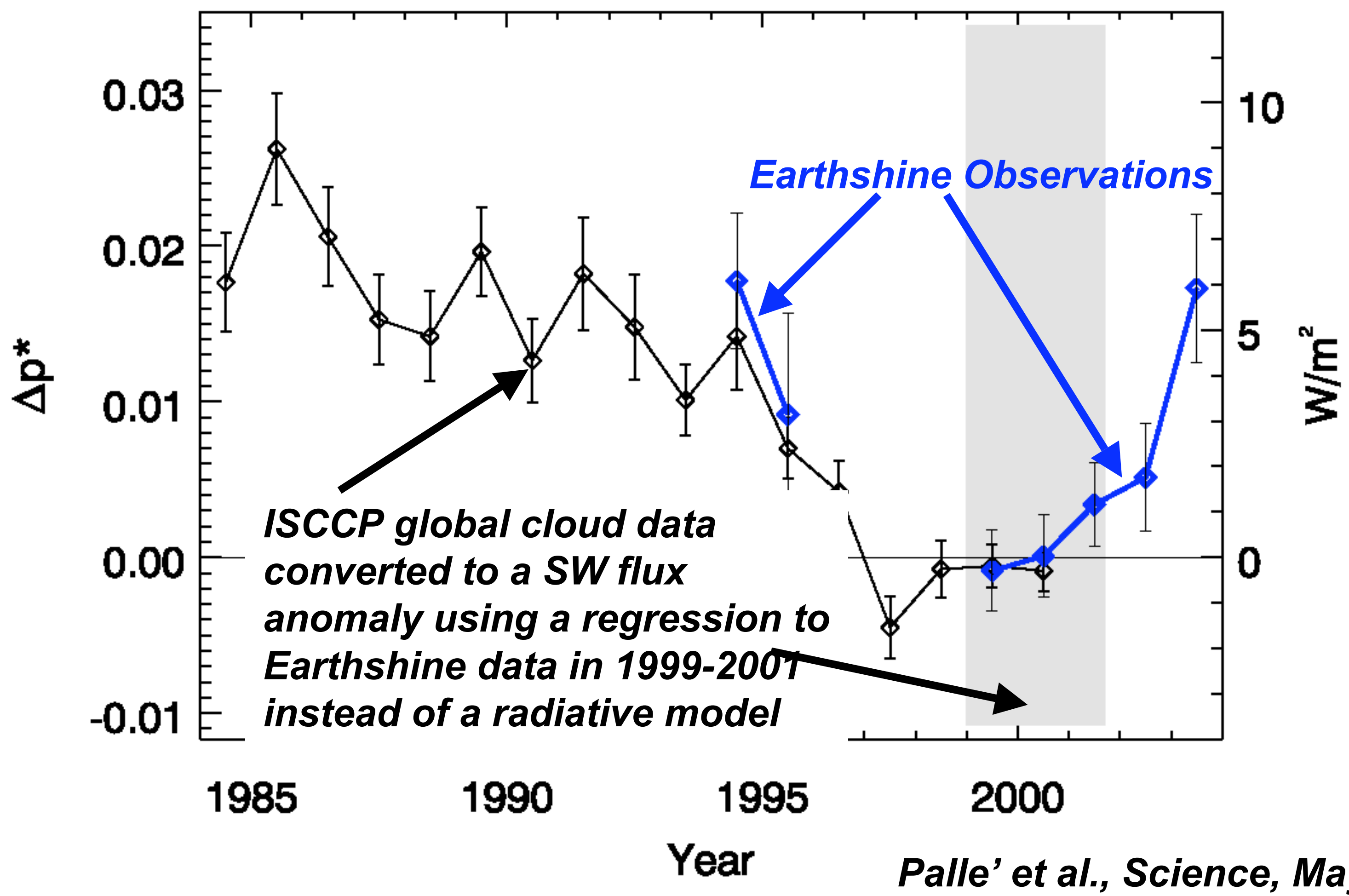
- Trend comparisons: top of atmosphere trend = $F_{94\text{-}97} - F_{85\text{-}89}$
- Sign of trend is positive for increased outgoing flux TOA SW,LW
- Sign of trend is positive for heating the Earth for TOA Net
-

Source	**Region**	**LW**	**SW**	**Net**
ERBS Ed2 WFOV	Tropics	+ 3.1	- 2.5	- 0.6
ERBS Ed3 WFOV (alt adj)	Tropics	+ 1.6	- 3.1	+ 1.5
ERBS Ed3 (+constant day/nite)	Tropics	+ 0.6	- 2.1	+ 1.5
ISCCP + radiative transfer	Tropics	+ 1.0?	- 2.5?	+ 1.5?
AVHRR OLR (Jacobowitz)	Tropics	- 2?	n/a	n/a
HIRS OLR (Susskind)	Tropics	+ 1?	n/a	n/a
SAGE III Cloud Vert. Dist. Changes	Tropics	+1.3	n/a	n/a

(scale 1.5 per decade to 8.5 years, assume no effective emissivity trends)

- Conclusion: diverse data sets are now much more consistent. No “tuning” of any of the data sets has been done.

Note: question mark (?) means value was taken roughly from a plot and not yet calculated with the underlying data.

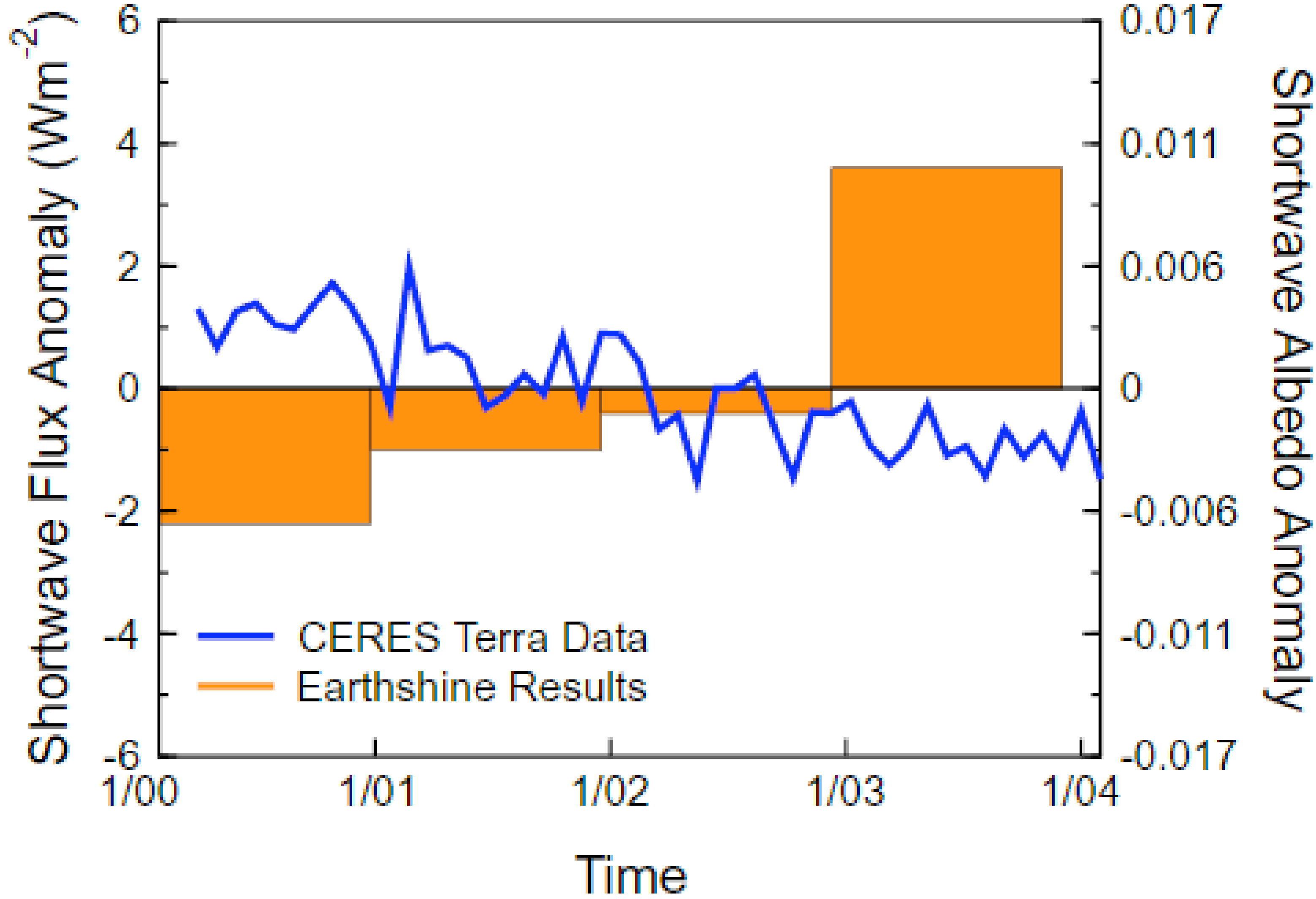


Palle' et al., Science, May 2004

Key earthshine concerns:

- ***observation is near direct backscatter peak, angle varies with lunar libration***
- ***only 1/3 of the earth viewed***
- ***varying CCD detectors used depending on libration: gain aliasing***
- ***visible albedo, but interpreted as if broadband: exaggerates cloud change***
- ***albedo and earthshine not uniquely related: can change one without the other: just spatially redistribute cloud within the large earthshine viewing region***

Earthshine Results versus CERES: 2000 to 2004

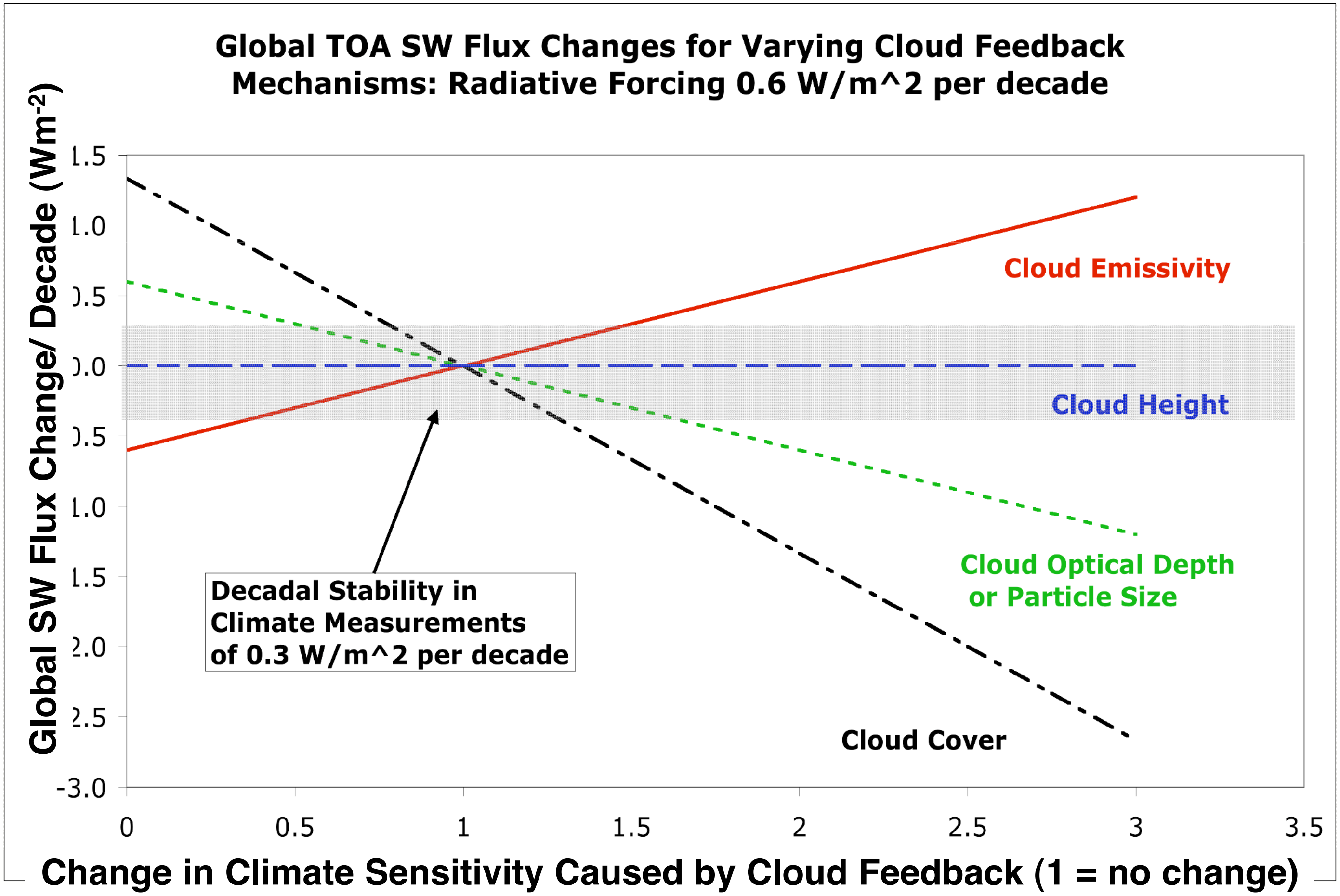


submitted to Science Brevia, Oct 2004

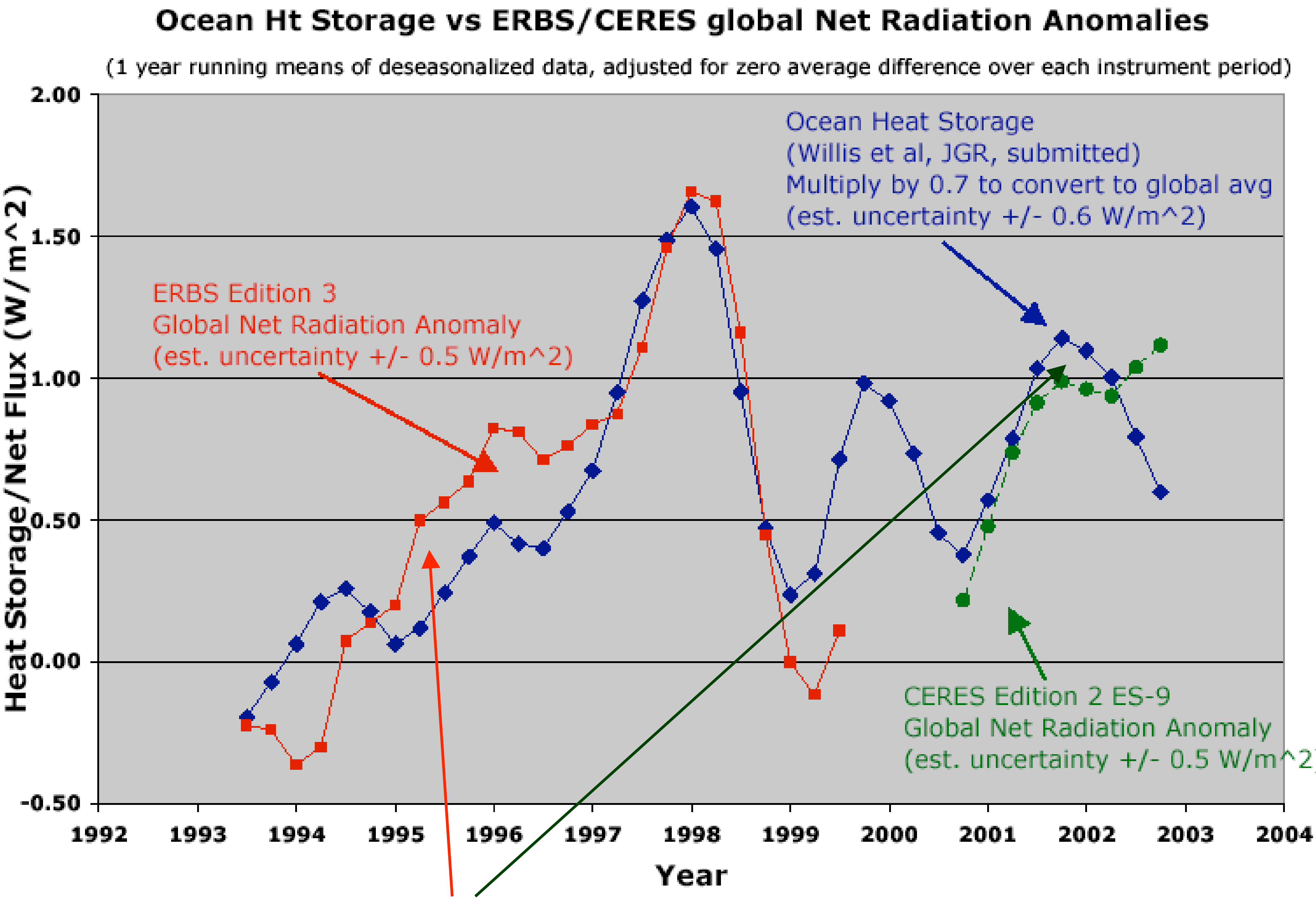
Global Dimming

- Surface Solar Insolation observations (GEBA):
  - 1960 to 1990 drop in insolation over land of -6 to -9 Wm^{-2}
  - Decrease in pan evaporation over the same period
  - Pan evaporation is only potential evaporation, not actual
  - Concern that GEBA radiation data not sufficiently calibrated for decadal monitoring
  - Attempts to use Sunshine duration data for the U.S. do not confirm global dimming: but this is a simple on/off switch at 120 Wm^{-2}
  - Thought to be increasing aerosols, especially absorption
- 1990 to 2000
  - BSRN data indicate some increasing solar insolation 90s to 2000 qualitatively consistent with ERBS/ISCCP albedo decrease
  - Publications submitted from 90s surface data.

How accurate must measurements be to constrain equilibrium global cloud feedback?



- Regional changes will be larger: but no regional “constraint” and global mean still must be accurately known for global feedback.
- UKMO ensemble climate noise for annual tropical mean SW and LW fluxes ~ 0.3 Wm^{-2}: this might be a reasonable lower limit on accuracy.



1 sigma agreement: 0.3 Wm^{-2}

10-yr Temperature Trends versus Ocean Depth

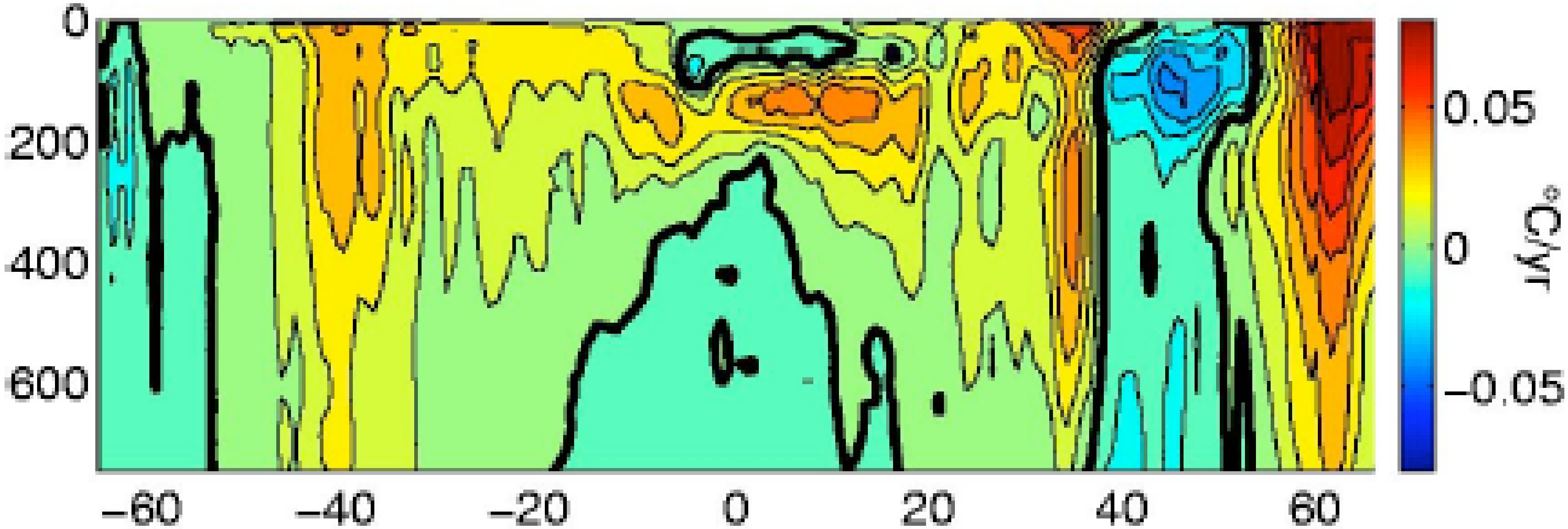
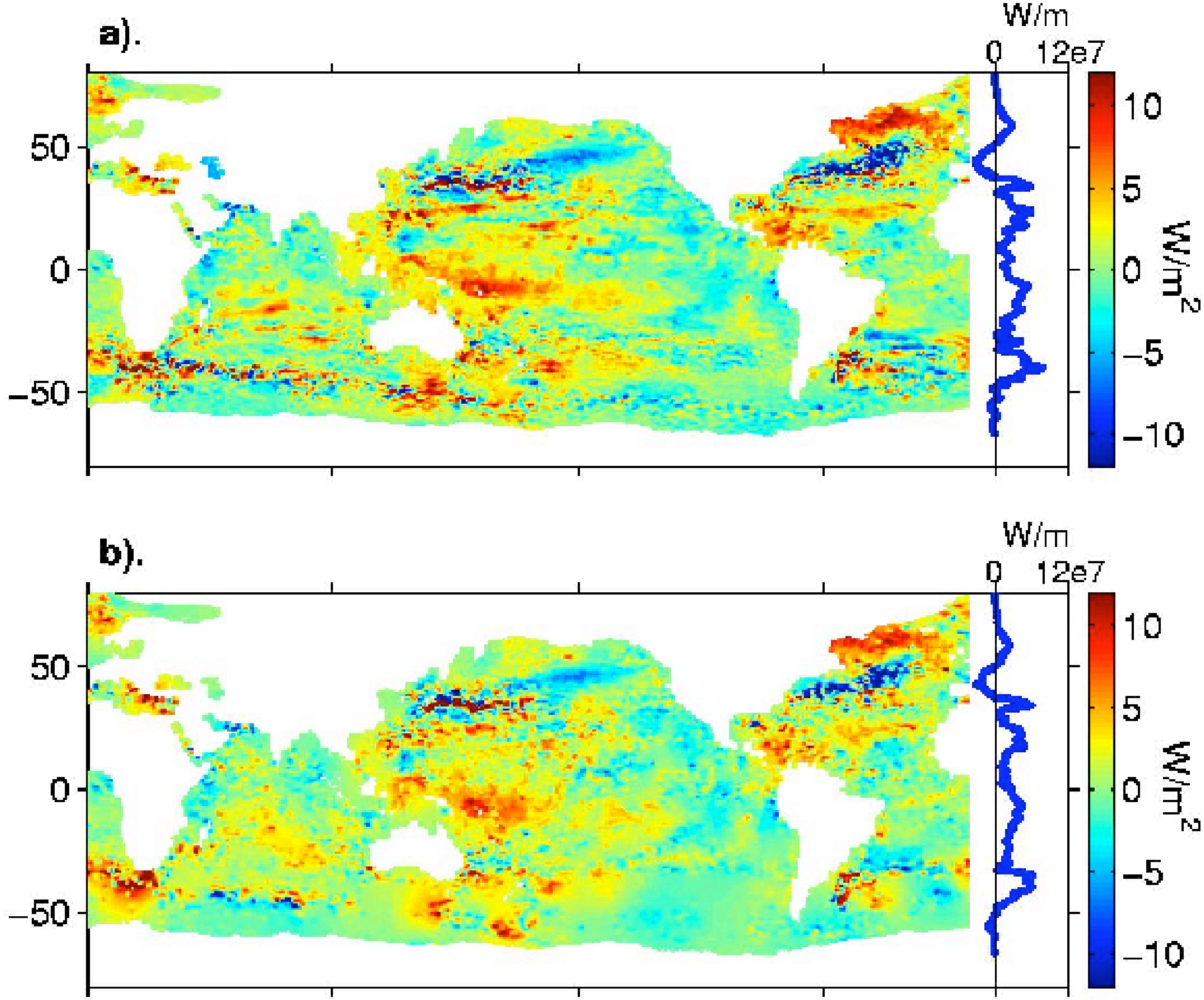


Figure 9. Ten-year trend in zonally averaged temperature vs. depth and latitude.

Willis et al, JGR, in press

Regional Ocean Heat Storage Variability: 1993-2002



Willis et al, JGR, in press

Heat Content Variability: Global and Tropical

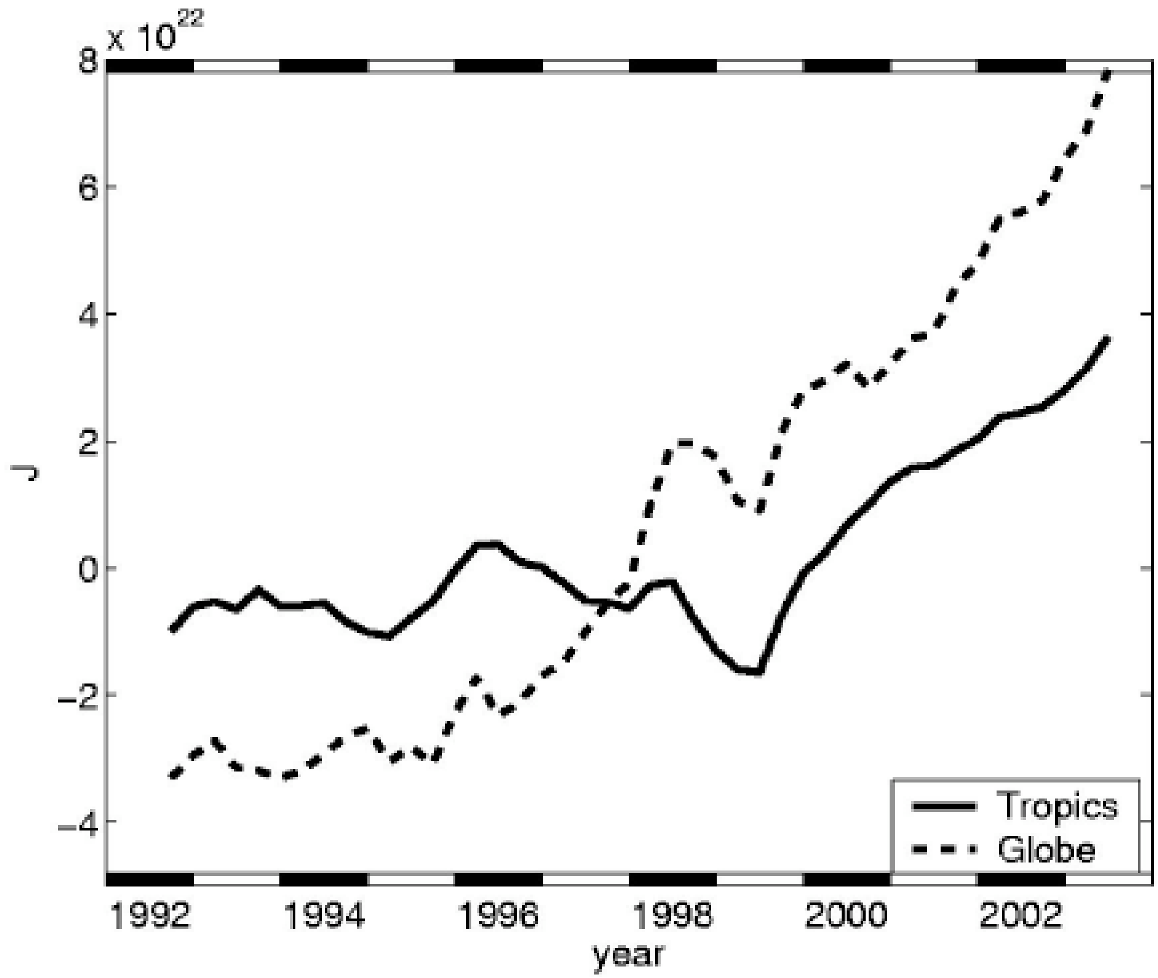
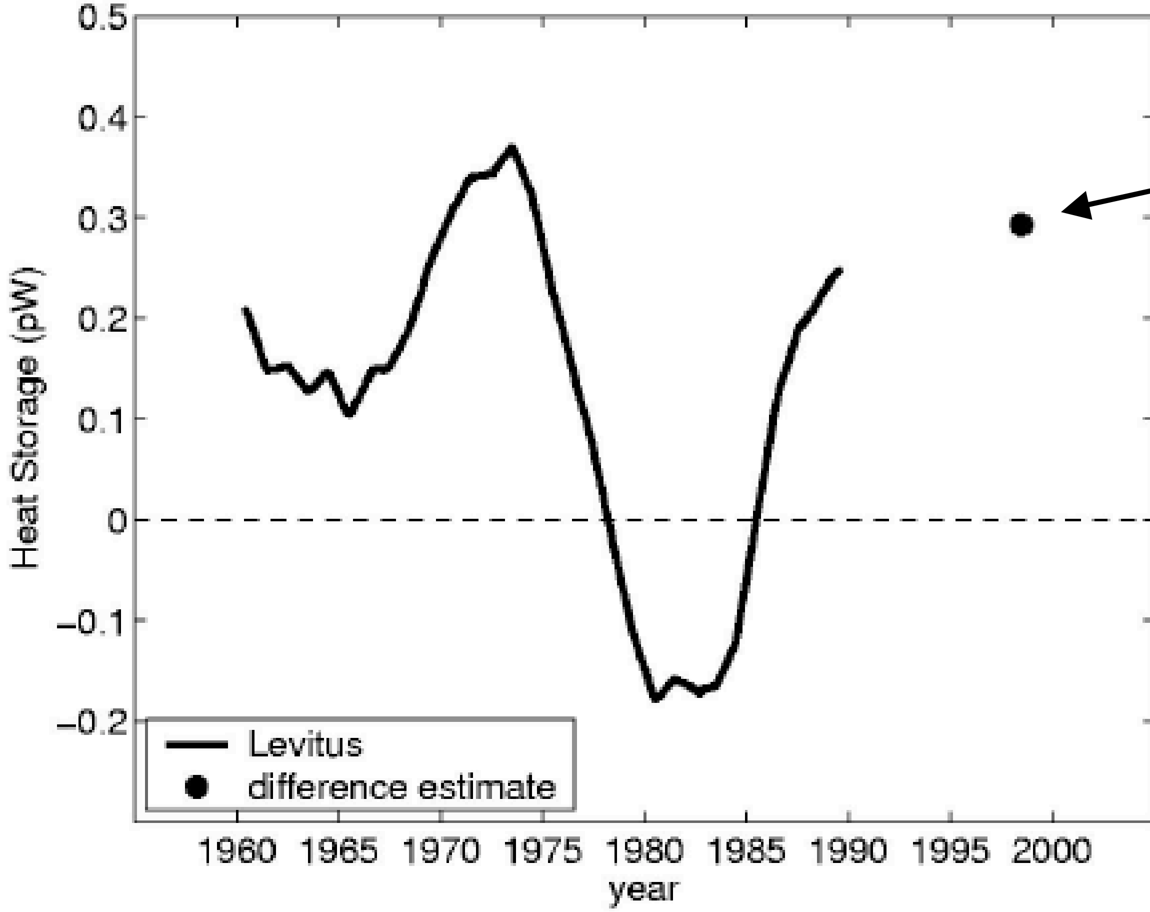


Figure 8. Interannual variability in heat content integrated over the region from 20° N to 20° S (solid line) and over the entire globe (dashed line).

Willis et al, JGR, in press

New Ocean Heat Storage Versus Levitus Data

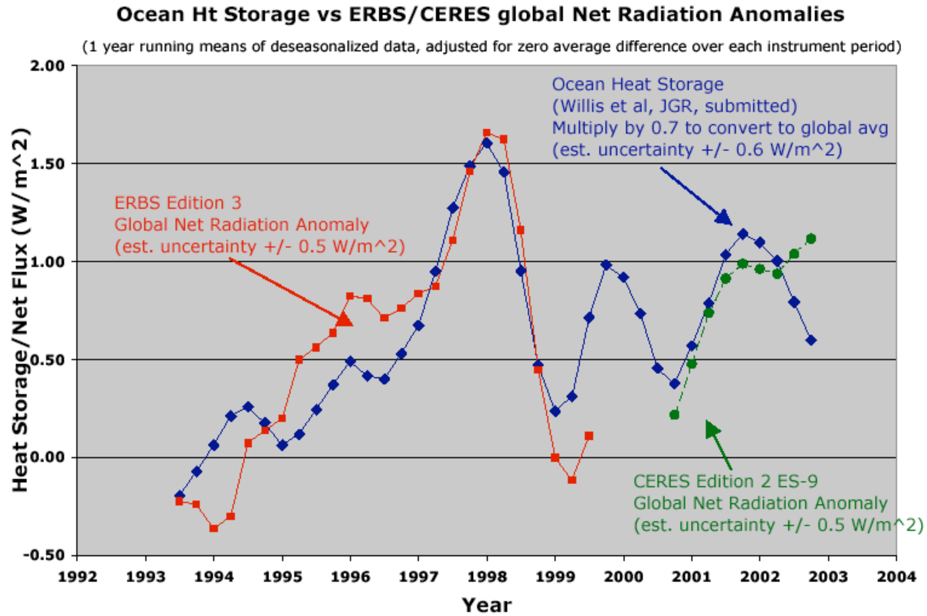


0.85 Wm^{-2} ocean,
0.6 Wm^{-2} globe

Figure 12. Decadal heat storage calculated as the 10-year difference of the 40-year time series of heat content published by *Levitus et al.* [2000a]. The single point represents the 10-year heat storage rate from the present analysis, as calculated in Section 3.1.

Willis et al, JGR, in press

What are the implications for climate modeling and climate sensitivity?



- ***Ocean heat storage variability is larger than thought (2 Wm^{-2})***
- ***Mean is well above zero: consistent with climate model predictions of global warming ocean heating: 0.5 to 1.0 Wm^{-2}***
- ***Variations mean variations in global net cloud radiative effect***
- ***For equilibrium climate change in global net CRE = change in climate sensitivity.***
- ***Observations are of non-equilibrium climate***
- ***How do we unscramble cloud feedback and ocean heat storage natural variability or forced variability?***
- ***Climate sensitivity a function of time as in Senior and Mitchell? (GRL, 2000)***

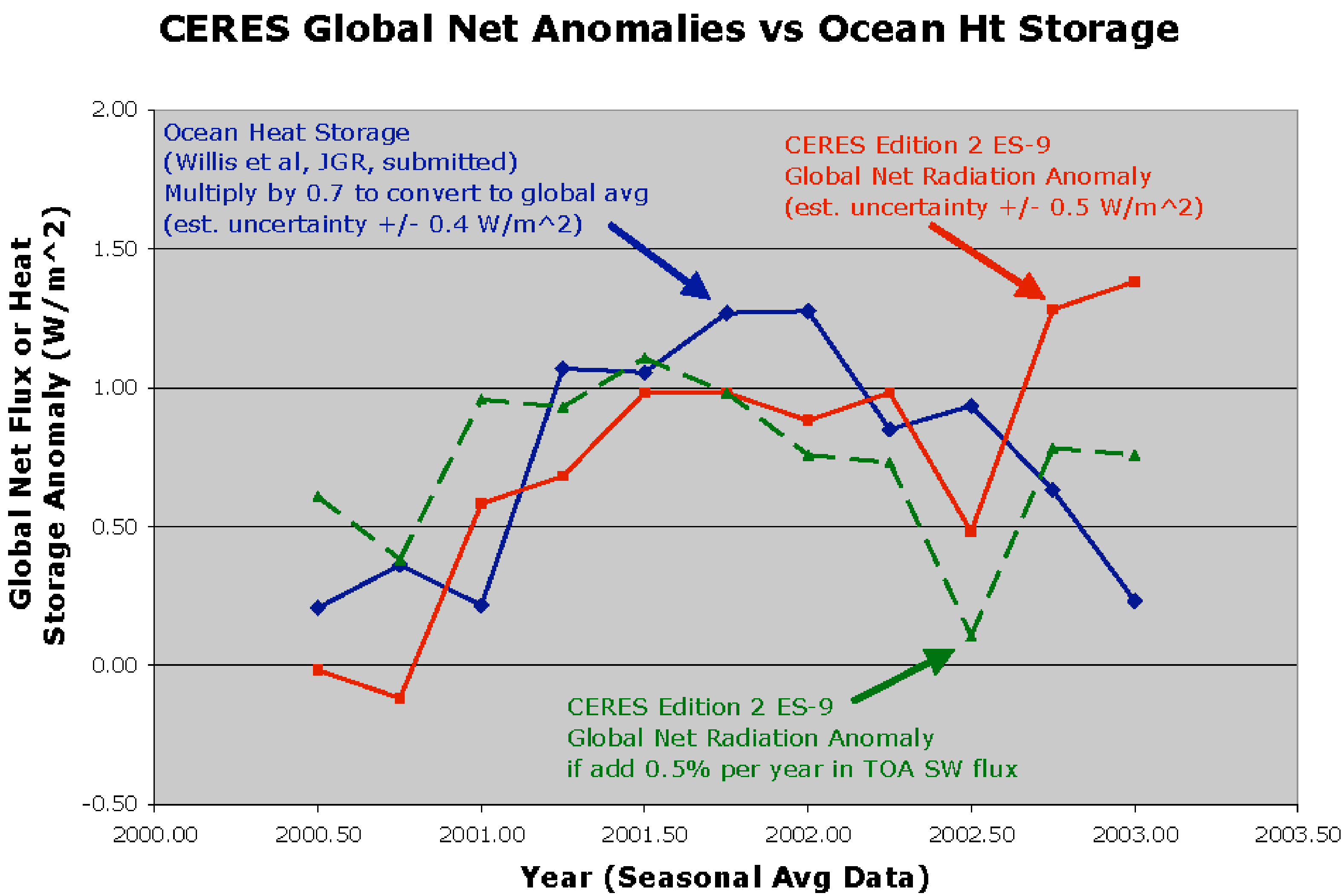
What are the next steps?

- Re-examination of CERES calibration results:
  - code
  - electronics (e.g. response as in window channel at very high SW: test in orbit)
  - ground cal tests of lamps
  - testing of alternative to lamps constant: assume total channel gain constant across SW and LW: 3-channel constraint on SW gain (e.g. deep convective cloud TOT - Window => SW.
  - assess results from MAM solar cals: have they stabilized? SW vs SW part of Total?
  - characterization tests that can be done with CERES FM-5 instrument on the ground

- Extend Ocean Heat Storage overlap with CERES to 4 years from current 2 years (work with Willis et al. at Scripps).

- Examine more closely any possible analysis bias from changing local time of day for Terra orbit: 1045am => 1030am.
  - Solar zenith change near equator of ~ 4 degrees (1hr ~ 15 deg)
  - cos(44)/cos(40) = 0.94, or 6% change in insolation.
  - in principle accounted for in current software. need to verify

What would CERES global net radiation vs ocean heat storage look like if added 2% SW TOA flux over 4 years: i.e. 0.5% per year?



What are the next steps?

- Complete CRS and SSF Ed2B comparisons with matched MODIS cloud and aerosol data (cloudy and clear-sky changes)
- Examine stability of SeaWIFS lunar calibration for vis channels
- Work with MODIS and MISR team on their calibration stability estimates from diffuser plates and lunar calibration
- Consider additional Terra lunar cals for MODIS and MISR
- Comparisons to ERBS SW channel in 2000 to 2003.
- Compare LW day/night trends to HIRS for 2000 to 2004 pathfinder data, this will be an independent constraint on day/night LW flux for 3-channel checks.

Backup Slides

How can we use observations to determine the uncertainty in climate predictions?

We are searching for a mapping function:

F(Climate Obs - Model Metrics) = G(Climate Prediction Uncertainty)

F = Observations minus Models for a range of key variables
at selected time and space scales

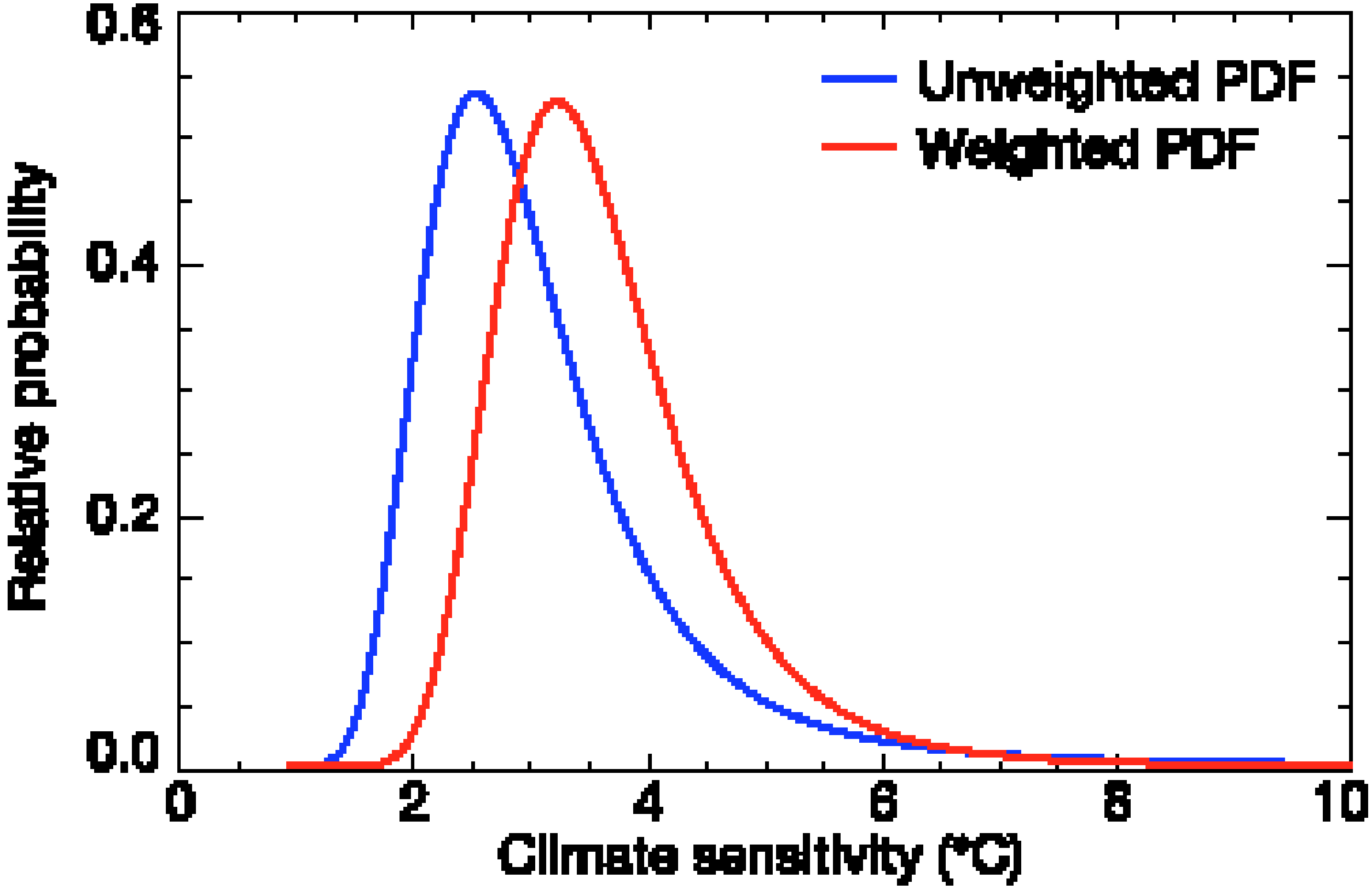
- global SST
- seasonal net global cloud radiative effect
- does it take 10? 50? 100?
- nonlinear relationships?

G = Uncertainty in key climate prediction variables/time/space scales.

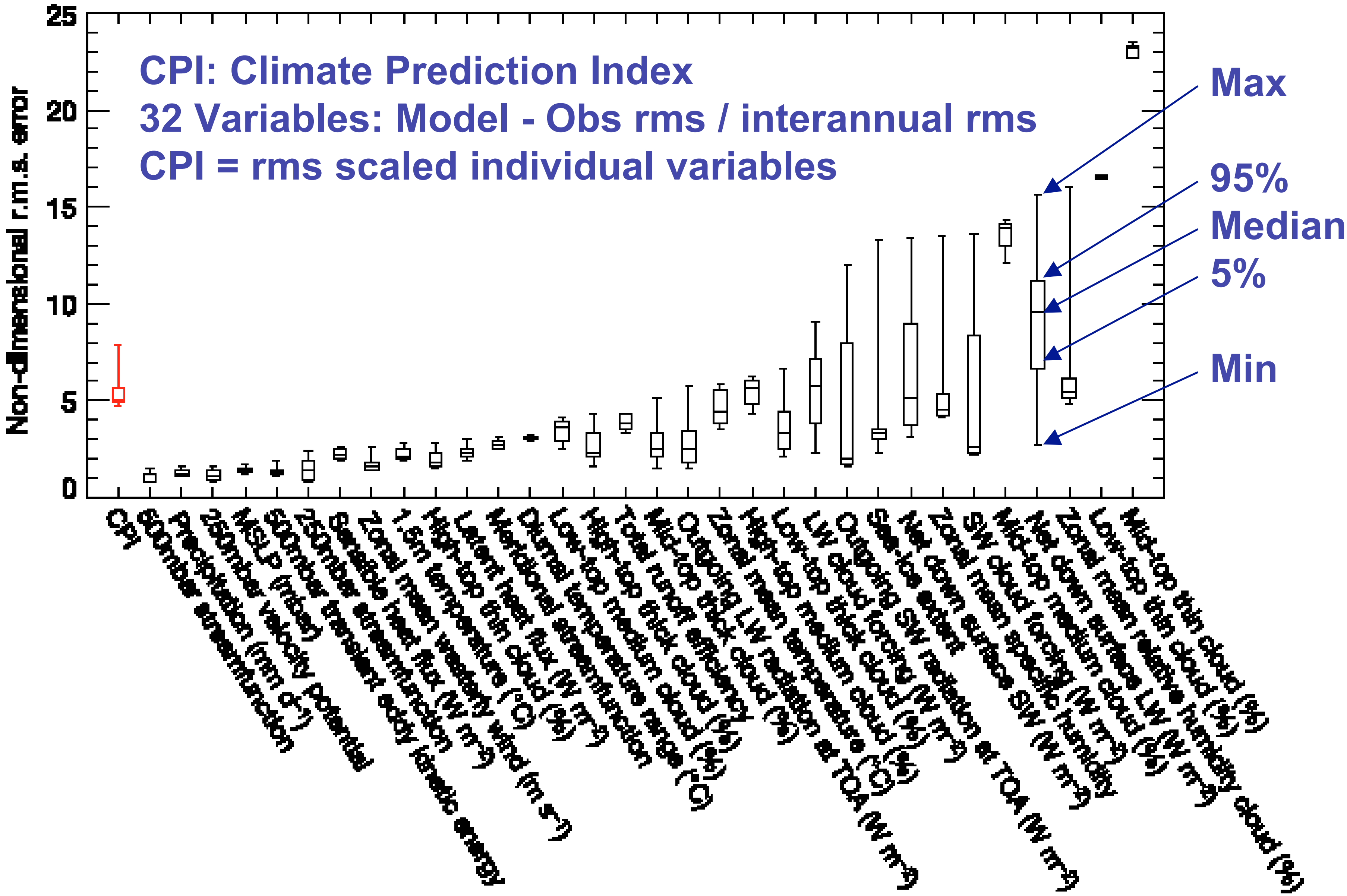
- global mean surface temperature
- summer mean european precipitation
- hurricane frequency

Perturbed Physics Ensembles: PPEs

53 runs of physically different Earth-like planets
Vary 29 HadAM3 sub-grid parameterizations within reasonable range
Each planet run in mixed layer mode for normal and doubled CO_2 cases



Murphy et al., Nature, Aug 7, 2004



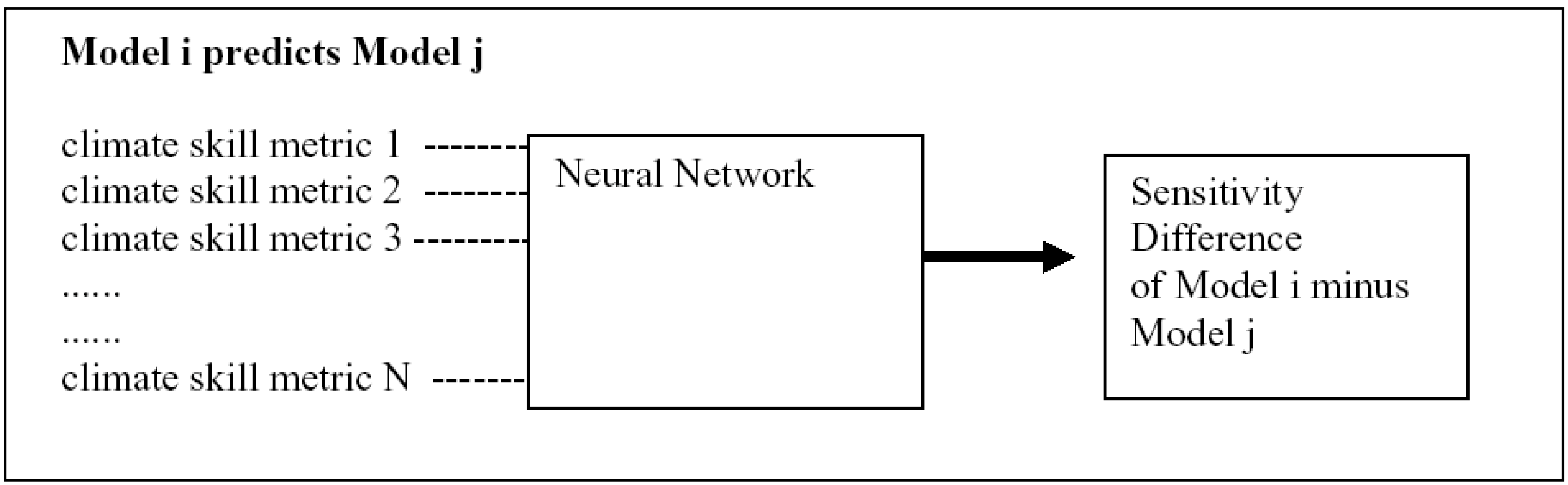
How can we more rigorously weight variables and time/space scales to predict uncertainty in climate prediction?

Murphy et al., Nature, Aug 7, 2004

Climateprediction.net: 1000s of Perturbed Physics Ensembles using UKMO model with mixed layer ocean.

Climate@home: similar using GISS coupled ocean/atmosphere

- From these 1000s of runs, 1000s of different earth-like planets
- For any two model runs, let model i be "Earth" and model "j" be the model
- Climate metrics for "i minus j" = observed minus modeled Earth (no obs error)
- Sensitivity for "i minus j" = climate sensitivity difference and is KNOWN
- Sensitivity not only for global surface temperature: regional summer precip, etc.



Over 1000s of model pairs in the PPE: let the varying model physics show how to optimize the selected climate metrics, and predict uncertainty.
Test robustness comparing other climate models (NCAR, LMD...) and other climate forcings (solar, volcanic, aerosol ...) Test observing system reqmts...

Climate Requirement Steps

- Define accuracy requirements: TOA & Surface Fluxes
  - As a function of time/space scale
  - Absolute/Precision/Stability
  - Independent observations critical (new climate observing sys reqmt)

- Ideal or "Goal" capability
  determine by climate model internal noise variability of mixed layer (atmosphere only) and coupled (ocean/atmosphere) runs

- "Minimum" capability determined by climate forcings and feedbacks as a function of time/space scale

- Climate models are 250km scale, need to use satellite data to show relationship of surface sites to larger time/space scales for sfc site reqmts.

- Long-term goal is to link requirements (variable/time/space) to impact on constraints for climate prediction (e.g. climate metrics tested using climate prediction.net and climate@home large ensembles

What about global net fluxes?

- ERBE was about 5 Wm^{-2} (heating) and was within its accuracy bound given calibration, angular sampling, and time sampling limitations
- CERES is reducing all major error sources and has a target uncertainty of about +/- 2 Wm^{-2} in global net.

	SW	LW
– calibration (absolute accuracy)	+/- 1.0	+/- 1.0
– spectral correction	+/- 0.1	+/- 0.1
– spatial sampling	0	0
– angle sampling (new ADMs)	+ 0.5	- 0.1
– improved reference altitude (20km)	+/- 0.1	+/- 0.2
– twilight shortwave flux (adds 0.25)	+ 0.1	0
– spherical earth near sunset/sunrise	< + 0.7	0
– cloud optical depth biases (solar zenith albedo)	+ 0.7	0
– new solar constant (1361 vs 1365)	+ 1.0	0
– time sampling (geo calibration aliasing)	+/- 0.4	+/- 0.1
– ocean heat storage constraint (2000/2001)	0.3 to 1.0	
– expected range in current SRBAVG product global net for 2000/2001:	2 to 6 Wm^{-2}	

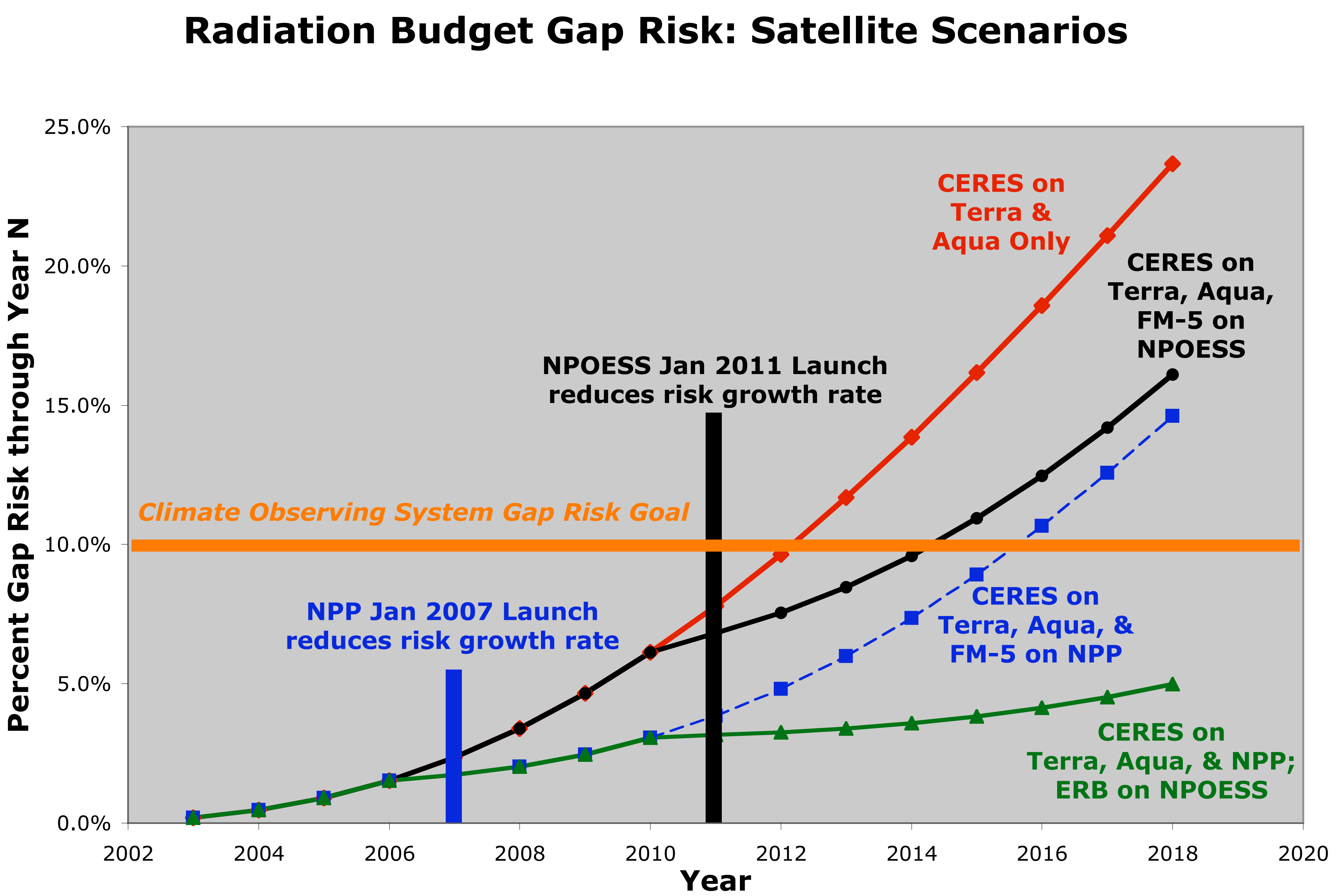
What about global net fluxes?

- Ocean Heat Storage variability:
  - Recent submitted paper on merged in-situ/altimeter heat storage for 1992 to mid-2002.
  - Interannual variations: 2 Wm^{-2} global mean
  - Single year annual sampling noise: 0.5 Wm^{-2} 1-sigma
  - 10 year average sampling noise: 0.1 Wm^{-2} 1-sigma
  - Completion of ARGO should cut errors in half (southern oceans)

- What is CERES interannual uncertainty in net flux year to year?
  - Calibration stability dominated: ~ 0.1 to 0.2 Wm^{-2}.
  - Global annual net Terra ERBE-Like first 3 years:
    - Time Period TOA Net
    - Mar 2000 - Feb 2001: 3.95
    - Mar 2001 - Feb 2002: 4.69
    - Mar 2002 - Feb 2003: 4.93

NIST/NASA/NOAA Satellite Calibration Requirements Workshop Report (March, 2004)

- Overlap critical for stability, decadal signals
- Goal for decadal stability: 0.3 Wm^{-2}
  - constrain cloud feedback to +/- 50% for 0.6 Wm^{-2} forcing/decade
  - UKMO ensemble tropical annual noise: 0.3 Wm^{-2}
  - impacts instrument overlap requirements
  - impacts completeness of sampling requirements
- Goal for absolute accuracy: 1 Wm^{-2}
  - absolute accuracy should not be too much worse than stability or second order bias errors can alias into stability change.
  - suggested absolute accuracy be no worse than 10 times stability/decade
- TOA flux goals and Surface flux goals similar: but logic not as clear: surface and latent heat fluxes can compensate.
- Did not deal with less stringent regional: we should do it here
- NIST report also considered many other variables such as cloud properties and used similar criteria.



Radiation Budget Gap Risk: Satellite Scenarios
Percent Gap Risk through Year N
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year
CERES on Terra & Aqua Only
CERES on Terra, Aqua, FM-5 on NPOESS
NPOESS Jan 2011 Launch reduces risk growth rate
Climate Observing System Gap Risk Goal
NPP Jan 2007 Launch reduces risk growth rate
CERES on Terra, Aqua, & FM-5 on NPP
CERES on Terra, Aqua, & NPP; ERB on NPOESS